THE NICKEL BULLETIN

A SUMMARY OF CURRENT INFORMATION ON NICKEL

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25 YEARS AGO *page* 107

	Page
General	
Filters made by Powder Metallurgy	108
Nickel	
Free Energy of Vaporization of Nickel and Other Metals	108
Field Emission from Nickel Surfaces	108
Catalytic Properties of Nickel, Cobalt and Nickel–Cobalt Catalysts	109
Clad Steel Plate: Manufacture and Properties	109
Electrodeposition and Other Coating Methods	
Cleaning of Metals for Electroplating	109
Peeling of Nickel Deposits: Causes and Prevention	109
Internal Nickel Plating of Tubing for Atomic-Energy Plant	110
Non-Ferrous Alloys	
Specification for Condenser–Tube Alloys	110
Centrifugal Casting of Nickel–Bronze Bearing Shells	110
Tungsten–base Heavy Alloys containing Nickel	110
Nickel Amalgams	111
Nickel-Iron Alloys	
Magnetism and Magnetic Alloys	111
Nickel–containing Materials having Special Magnetic Properties	113
Magnetostriction Characteristics of Alnico V Alloy	113
Properties of Invar: Theoretical Discussion	113
Cast Iron	
Machinability Tests on Plain and Low–Alloy Cast Irons	114
Ni–Hard in Clay–Working Machines and Gravel Pumps	114
Data Sheet on S.G. Iron	114
Cast Iron (*contd.*)	
Heat–Treatment and Properties of S.G. Iron	114
Review of Current Industrial Applications of S.G. Iron	114
Engineering Applications of S.G. Iron	115
S.G. Iron in Agricultural Machinery	115
Constructional Steels	
Austenite–Martensite Transformation in Iron–Nickel–Manganese Alloy	115
Continuous–Cooling Transformation Diagrams for Nickel–Alloy Steels	115
Machinability of Cast Steels	116
American Iron and Steel Institute Constructional–Steel Specifications	116
Dilatation Tests for Assessment of Weldability	116
Heat- and Corrosion-Resisting Alloys	
Creep Tests on Nimonic Alloys under Cyclic Stress and Temperature Conditions	117
Machining of the Nimonic Alloys	118
High–Temperature Properties of 18–8–Mo Steel	118
Radiation–Suppressing Coatings for Nickel–containing High–Temperature Alloys	118
Strain–Induced Martensite Transformation in Austenitic Nickel–Chromium Steel	119
Hardening of Austenitic Chromium–Nickel Steels at 475°C.	119
Oxygen on the Surface of Passive Stainless Steels	120
Corrosion– and Heat–Resisting Alloy: Hastelloy F	120
Resistance of Stainless Steel to Organic Compounds	121
Stainless Steels for Chemical Plant: Compositions and Properties	122
'Carbidizing' Process for Surface Hardening of Stainless Steels	122
Patents	123

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25 YEARS AGO

THIS journal, which was first published in July 1928, has continued without interruption ever since, although changes in paper, in format and in contents reflect such major events as the Great Depression, the War, paper shortages and temporary restrictions in the use of nickel.

These 25 years have witnessed many industrial developments but we must resist the strong temptation towards a series of detailed references from the 24 volumes. Suffice it to mention that Volume 1 No. 1 contains a reference to the introduction of the now famous Bash and Harsch test of 'Nickel–Chromium Resistor Materials', that Alloy Cast Irons were only then beginning to be accepted, and that in No. 2 there is a reference to the 'fabrication difficulties' encountered with stainless steels. In common with many other difficulties these have been overcome; but as the fringes of technical knowledge advance fresh difficulties and problems appear. Thus, the reasons which led to the introduction of the *Nickel Bulletin* still hold good. As was said in our first leading article, entitled 'Our Aim':

'These are days of intensive research in all directions, and in no field is the effect of this felt more than in those which have to do with the production and utilization of metals and alloys. In the laboratories of the Universities, Government establishments and works, large and small, investigation into the properties and uses of metals is continually proceeding. Almost daily fresh data are being brought to light and fully accepted theories are being modified or discarded. New combinations of metals are being devised which often replace alloys of well-established utility, while on the other hand comparatively slight modifications in the composition or treatment of well-known alloys develop in them characteristics which open up entirely new fields of usefulness.

'In the workshops themselves developments are taking place more rapidly as a result of the greater scientific control of processes which has gradually been introduced during the past few decades. Improvements in the methods and technique of casting, forging, rolling, heat treatment and all the many means of dealing with metals are frequently taking place. The whole science and practice of metallurgy is continually in a state of flux and making rapid strides forward....

'Further, the very rapidity of the advances which are being made make it essential that any one dealing with metals, either in manufacture or utilization, should be aware of the results which apply to his own particular field at the earliest possible moment. Not only may they be applicable immediately to his own practice, with a resulting saving in expense or increase of efficiency, but they may make the carrying out of a projected investigation unnecessary or, alternatively, suggest a further line of work for the more rapid solution of some particular, troublesome problem.

'Such is the volume of printed matter appearing, however, that the searcher after information has to wade through a mass of periodicals, journals, etc., the major contents of which have no interest at all to him, just in order that he may not miss any point that is of importance. Even articles on his own subject often give no fresh information, since there is much repetition.'

We also pointed out that 'even the best of abstracts may miss just that point in which you are most interested, so we suggest that the details given here be regarded simply as indicative of the scope of publication during the month, and strongly urge that where the matter appears interesting an effort be made to see the original. Local libraries are often helpful in this direction, while most of the Technical Societies and Institutes take in a selection of periodicals which they are prepared to loan soon after the issue has ceased being current'.

As in 1928, we still welcome suggestions regarding the scope of the matter included and the method of its presentation. Our aim is to be of service wherever application is found for the many and varied properties of nickel and its alloys.

ABSTRACTS OF CURRENT PUBLISHED INFORMATION ON NICKEL AND ITS ALLOYS

GENERAL

Filters made by Powder Metallurgy

A. J. LANGHAMMER and P. GLICK: 'Metal Powder Filters.' *Product Engineering*, 1953, vol. 24, Apr., pp. 179–82.

Progress in technology in various branches has led to a growing demand for filters of increased efficiency: today, in varying forms, filters are employed for many applications in the chemical-engineering and other industries. Production by powder-metallurgy methods is found to be a highly satisfactory method of securing the control of porosity and other properties required: many forms of filter are now being made by this procedure, using bronze, stainless steel, nickel silver or other material, selected according to the service for which the units are intended. This article gives some typical property data for filters of various forms, and discusses the information needed for design and specification.

Typical current applications of powder-produced filters include:—

(1) *Filtering* of all types of fluid, ranging from fuel oil and petrol to corrosive liquids and air.

(2) *Diffusing*, e.g. in dehydrators for diffusing air round a drying agent, such as silica gel, for effective removal of moisture. Diffusing air for aeration of water or liquid is another common application.

(3) *Separating*. An outstanding use in this connexion is that of permanent filters in the petrol tank of Chrysler cars, where operation is based on the physical law that two immiscible fluids of different surface tension cannot 'take possession' of a surface simultaneously. The fluid first wetting or 'taking possession' of the surface will flow through, to the exclusion of the other. Water present in the fuel tank is thus kept out of the system, preventing the freezing of fuel lines. A feature of the filter is that it is self-cleaning.

(4) *Metering*. A general industrial application of this type is in a compressor air line, between the pressure gauges and the main line, where a filter is used to protect instruments from extreme shock resulting from instantaneous change of line pressure. These filter plugs damp out pulsations and vibrations, thus permitting the gauges to record average readings: they simultaneously prevent contaminated oil from reaching operating parts. Use of filters as meters in lubricating systems is also described.

(5) *Flame arresting*. In various types of electrical equipment operating in inflammable atmospheres filter discs in the housing afford protection against explosion. The mass of the filter absorbs and dissipates the heat of the spark or flame, while its high permeability allows cooled gases, products of combustion, to pass through harmlessly.

(6) *Sound damping*. In pneumatically driven equipment the use of powder-metal filters in the air-escape openings permits an increase in the area of the outlets, thus lessening noise. They have the additional advantage of protecting the mechanism from the entrance of dust.

Typical filters used in the various applications are illustrated.

NICKEL

Free Energy of Vaporization of Nickel and other Metals

J. W. EVANS: 'Free Energy of Vaporization of Metals from 0° to 2000°C.' *Jnl. of Metals*, 1953, vol. 5, May, Sect. 1; *Trans. Amer. Inst. Mining and Metallurgical Engineers*, pp. 655–6; T.P. 3476D.

The note gives a graphical representation of free energies of vaporization of over 20 metals considered to be of economic importance. Although the main purpose of the chart is to make possible calculation of free energies, it also shows the relative volatilities of the metals over the whole temperature range considered. Mode of using the diagram is described in detail.

Field Emission from Nickel Surfaces

R. GOMER: 'Field Emission from Nickel Surfaces.' *Jnl. Physical Chemistry*, 1953, vol. 21, Feb., pp. 293–303.

The development of the field-emission spectroscope (see reference *ibid.*, 1953, vol. 21, p. 73) has made possible the study of single-crystal metal surfaces under much cleaner conditions and with more resolution than is possible with other methods. Most field-emission work has been done on tungsten and molybdenum (probably due to the greater ease of preparation of emission points in these high-melting and mechanically strong metals), and much information has thus been obtained, but from the purely chemical point of view somewhat greater interest attaches to the transition metals, with their *d* bands, and consequent high catalytic activity. For this reason a study of the emission characteristics of nickel was undertaken. Observations were made on clean and on silicon-contaminated surfaces of nickel wire.

The results are given in detail, and the report is well

illustrated. It is concluded that the equilibrium shapes of nickel single crystals are close to spheroidal, with flat regions at low index directions. Evidence for the formation of surface phases of carbon, silicon, and oxygen on nickel is presented. A method for studying the diffusion of silicon in nickel is described, and chemisorption of oxygen on nickel is discussed. A method for investigation of grain-boundary migration is also given.

Catalytic Properties of Nickel, Cobalt, and Nickel-Cobalt Catalysts

F. LIHL, H. WAGNER and P. ZEMSCH: 'Catalytic Properties of Nickel and Cobalt Powders for Hydrogenation, as a Function of Conditions of Preparation.' *Zeitsch. für Elektrochemie*, 1952, vol. 56, pp. 612–19.

The hydrogenation of benzene was studied in a flow system, at constant flow rate, temperature, and composition of mixture ($C_6H_6:H_2=1:5\cdot8$), over a series of nickel and cobalt powders prepared in different conditions from a variety of reagents. The work provided ample demonstration of the dependence of catalytic activity on method of preparation. It was found that, at equal weights, cobalt is considerably more active than nickel, and whereas the activity of cobalt increases with time, that of nickel decreases with use.

F. LIHL, H. WAGNER and P. ZEMSCH: 'Catalytic Properties of Alloy Powders in the Systems Cobalt–Nickel and Cobalt–Iron.' *ibid.*, pp. 619–24.

Powders of cobalt–nickel and cobalt–iron alloys were prepared from formate mixed crystals, according to a method previously described and tested. The phases were determined by X-ray analysis, and catalytic activity for hydrogenation of benzene was measured. For summary of results, see *Chemical Abstracts*, 1953, vol. 47, p. 2584.

Magnetism and Magnetic Alloys

See abstract on p. 111.

Clad Steel Plate: Manufacture and Properties

T. T. WATSON: 'The Manufacture and Properties of Clad Steel Plates.' *Blast Furnace and Steel Plant*, 1953, vol. 41, Mar., pp. 318–20, 326–7, 351, 354–5.

The increase in production of clad steel plate, since the development of nickel-clad steel in 1930, is illustrated by a curve showing figures for the 1939–1951 period.

The article is concerned with the method of production used by the Lukens Steel Company, which is a heat-and-pressure technique. The principle of this method consists in heating a pack or sandwich made up of cladding metal and carbon steel components, heating to high temperatures, and applying pressure to achieve the desired bond. In the Lukens process the pressure is obtained by means of a rolling mill. Two main techniques are used: (1) direct bonding of the cladding metal to the carbon steel, and (2) bonding by use of an intermediate metal, such as nickel or iron, in the form of plating. The direct-bonding process is used for manufacture of nickel- and Monel-clad plates, and the nickel-plating technique for all types of stainless-, Inconel-, and copper-clad steels. The various steps of the processes are described by the author. The heat-and-pressure method provides great uniformity of cladding, a feature which is of considerable importance, particularly in connexion with the welding of clad plate.

After short notes on fabrication, details are given of some of the tests which are regularly used for assessment of the properties of clad products. These include tensile, cyclic heating and quenching, hot-shear, and corrosion tests. Typical results obtained from clad plate in such tests are shown, and particulars are given of thermal-conductivity values of stainless-clad steels. Factors affecting the bond strength between basis and cladding metal are discussed.

ELECTRODEPOSITION AND OTHER COATING METHODS

Cleaning of Metals for Electroplating

H. B. LINFORD and E. B. SAUBESTRE: 'Cleaning and Preparation of Metals for Electroplating: V. Oil-Spreading Rates.' *Plating*, 1953, vol. 40, Apr., pp. 379–86.

This report covers laboratory work done during the first part of 1951, in connexion with A. E. S. Research Project No. 12. The object of this phase of the work was to determine the spreading rates of oils under conditions in which the atomizer test may be used industrially, and to ascertain the effect of oil spreading on the cleaning-index values obtained with this test.

The spreading rates of several oils on steel surfaces were determined: the results are summarized as follows:—

'Oils which adsorb strongly to clean surfaces (e.g., oleic acid) spread least; non-adsorbing oils (e.g., mineral oil) spread rapidly. Fatty oils (e.g., lard oil) are intermediate in behaviour. Spreading rates are higher on matte surfaces than on polished surfaces. Films of stearic acid render metal surfaces oleophobic; films of oleic acid render them oleophilic.

'In the light of the results obtained, cleaning-index values previously obtained for the waterbreak and atomizer tests are corrected for oil-spreading effects. The atomizer test remains the more sensitive one.'

Peeling of Nickel Deposits: Causes and Prevention

E. T. RICHARDS: 'Notes on the Peeling of Nickel Deposits.' *Metal Finishing*, 1953, vol. 51, Apr., pp. 64–7; May, pp. 60–5.

This is an essentially practical discussion of causes of peeling and methods of prevention, in sections dealing with the following aspects of the subject: adsorption of hydrogen during pickling, electrolytic cleaning, and nickel plating; faulty cleaning and rinsing of the basis metal; presence of metallic impurities in the electrolyte, e.g., iron, zinc, cadmium, lead, aluminium; influence of chromic acid; excessive concentration of organic

acids; excessively high or low pH of the solution; presence of organic impurities; influence of oxidizing agents used to purify the solutions; incorrect operating temperatures; excessive concentration of nickel salts or of conducting salts; cyanide contents; excessive current densities; presence of oil and other impurities on the surface of the bath; excessive amounts of brightening agents.

The final section of the review gives a classified list of 'symptoms', with notes on the probable cause(s) giving rise to the particular defects. In this connexion the following characteristics of defective deposits are considered:

deposit is dark and peels
" looks normal, but peels
" is bright, hard, and brittle
" can be pulled off
" can be rubbed off and is dark
" comes off in flakes
" which should be bright becomes dark and stained, and peels
" is dull and peels
" is discoloured, stained and striped, and peels
" which should be bright becomes dull and stained, and easily flakes off

A selected *bibliography* of pertinent literature (1922–1941) is appended to the review.

Internal Nickel Plating of Tubing for Atomic-Energy Plant

'Pipe: Nickel Plated Fast for A.E.C.' *Iron Age*, 1953, vol. 171, May 14, p. 82.

Short note on project for nickel plating of piping (2–54 in. diameter) by the Bart process. The plated product is to be used in various plants operated by the Atomic Energy Commission. An important feature in the electrodeposition equipment which is now being constructed is a single-cubicle selenium rectifier, believed to be the largest of its type in the world; it is made by Continental Copper and Steel Industries, Inc. The unit is illustrated in this article.

Civilian applications of internally plated pipe are in the oil, chemical and paper industries.

NON-FERROUS ALLOYS

Specification for Condenser-Tube Alloys

BRIT. STANDARDS INSTN.: 'Solid Drawn Copper and Copper Alloy Tubes for Condensers, Evaporators, Heaters and Coolers.' *B.S.* 378: 1953.

This Standard was first published in 1930: it then covered 70–30 brass and 70–29–1 (Admiralty mixture) tubes. The 1953 revision includes, in addition to these alloys, tubes in copper, aluminium brass, copper-nickel, and aluminium bronze (7 per cent. aluminium).

The specification includes requirements as to freedom from defects and dimensions, and gives details of hydraulic, drift, flattening, hardness, and mercurous-nitrate tests to which tubes of all types are to be subjected. Tolerances on outside diameter, thickness, and length are also shown.

The limits of composition laid down for the copper-nickel tubes are as follows:—

	%
Nickel	30·0—32·0
Iron	0·40—1·00
Manganese	0·50—1·50
Total of elements other than nickel, iron, manganese and copper	0·30 max.
Sulphur	0·08 max.
Copper	remainder

Centrifugal Casting of Nickel–Bronze Bearing Shells

J. TAYLOR: 'Difficulties in the Production of Centrifugally-Cast Nickel-Bronze Bearing Shells.' *Inst. Brit. Foundrymen*, Paper 1068, June, 1953, 9 pp.

In the production of shells for Babbitt-metal-faced Diesel-engine bearings, Messrs. David Brown Foundries Company use a nickel bronze, of which the following is the nominal composition: nickel 18, tin 5, lead 5, per cent., balance copper. The alloy is required to be substantially free from zinc, silicon, and aluminium, since these elements are believed to impair the adhesion of the Babbitt metal. A minimum Brinell hardness of 100 is specified. The shells are made by the horizontal-axis centrifugal-casting method.

As a result of the occurrence of pinholing in the Babbitt facing of some of the shells, a detailed investigation was made of the cause of the defect. This was traced to slight porosity in the basis metal. During the metallizing process gases, whether trapped in the pores or derived from the flux, form bubbles in the Babbitt metal, and, on subsequent machining of the faced shell to finished size, depressions are left at these positions on the surface. It is believed that this inter-dendritic porosity in the backing metal is due to gas evolution in the later stages of the solidification of the copper alloy, and that this gas forces the lead, which is then still liquid, out of the regions in which the evolution occurs.

The following methods of preventing the original solution of the gases were tried: avoidance of the use of gassy ingots; addition of small amounts of titanium; melting under an oxidizing flux and inert-gas scavenging of the metal. All proved unsuccessful, and certain modifications in processing, such as changes in pouring temperature and speed of rotation of the casting, also had little effect. It was found, however, that complete suppression of gas porosity can be achieved by careful adjustment of rates of cooling of the castings, and segregation due to micro-banding can be reduced to negligible proportions. Details of melting and casting technique are given.

Magnetism and Magnetic Alloys

See abstract on p. 111.

Tungsten-base Heavy Alloys containing Nickel

K. ROSE: 'High-Density Alloys for Heavy-Weight Applications.' *Materials and Methods*, 1953, vol. 37, Apr., pp. 86–9.

The article deals with the properties and uses of high-density alloys, made by powder-metallurgy methods,

under various trade names. Since the heavy-metal parts are made by pressing and sintering the mixed metal powders, density and strength of the finished material can be varied by modification of operating conditions: typical strengths and densities for parts of varying weight are quoted by the author, and some notes are added on variations in fabrication conditions which significantly affect the properties of the finished products.

Attention is drawn to a new method for making parts of high-density alloys, developed by P. R. Mallory and Company, Inc. This process, known as 'contour pressing', involves special procedure by which it is possible to produce parts of uniform density, in unusual and non-symmetrical shapes varying greatly in section thickness. It is claimed that the contour-pressing technique eliminates cracking in the pressed-metal parts and also overcomes risk of distortion.

The applications of the high-density alloys (the most generally used of which contains tungsten 90, nickel 6, copper 4, per cent.) are in two main fields: (1) those in which heavy weight in small bulk is essential, and (2) as shields against radioactivity. Typical parts in these categories include weights used for static and dynamic balancing, rotating inertia members for positioning of instruments, etc., vibration-damping members (e.g., to reduce chattering of tools), and radioactive shields where, in many cases, containers carrying radioactive materials must be of small size, while simultaneously giving maximum possible X-ray absorption.

Nickel Amalgams

F. LIHL: 'Investigations on the Amalgams of Manganese, Iron, Cobalt, Nickel, and Copper.'
Zeitsch. für Metallkunde, 1953, vol. 44, Apr., pp. 160–6.

Detailed report of the laboratory production and examination of the amalgams mentioned in the title of the paper. These can be divided into two groups:—the amalgams of iron and cobalt may be regarded as suspensions of the elementary metals in mercury, whereas nickel and copper form, with mercury, well-defined compounds. The nickel-mercury phase has a simple cubic structure and is continuous over the composition region $NiHg_4$ to $NiHg_3$. Stability of the amalgams in contact with oxygen increases in the following order: manganese, iron, cobalt, nickel, copper. In the dry state $NiHg_4$ is stable at room temperature in oxygen for two hours, and in air for about 20 hours. Oxidation results in partial elimination of mercury, and formation of an isomorphous mercury-nickel oxide of rhombic structure, having the formula $Hg_xNi_{1-x}O_2$.

Catalytic Properties of Nickel, Cobalt, and Nickel-Cobalt Catalysts

See abstract on p. 109.

Clad Steel Plate: Manufacture and Properties

See abstract on p. 109.

Filters made by Powder Metallurgy

See abstract on p. 108.

NICKEL-IRON ALLOYS

Magnetism and Magnetic Alloys

'Conference on Magnetism' 1952. *Rev. Modern Physics*, 1953, vol. 25, Jan., pp. 1–351.

This issue of the journal contains the papers and discussions presented at the Washington Conference on Magnetism held at the University of Maryland in September, 1952. The conference was sponsored by the U.S. Office of Naval Research, and its purpose was to bring together scientists interested in the subject and to review the present status of outstanding problems in this field.

The papers covered many aspects of experimental and theoretical magnetism: a list is given below of papers containing specific reference to nickel-containing materials.

E. C. STONER: 'The Analysis of Magnetization Curves.' pp. 2–16.

Analysis of magnetization curves is taken as meaning the determination of the character and extent of the various elementary changes occurring over any part of the curve. Includes data on annealed nickel, hard-drawn iron and other materials.

W. SUCKSMITH, C. A. CLARK, D. J. OLIVER and J. E. THOMPSON: 'Spontaneous Magnetization:Techniques and Measurements.' pp. 34–41; disc. p. 41.

Describes improved techniques recently developed. Includes data on nickel-copper alloy (27·5 per cent. copper), and nickel.

R. M. BOZORTH: 'The Permalloy Problem.' pp. 42–8.

The work described, comprising an investigation of the magnetic crystal anisotropy and the magnetostriction of single crystals of these alloys, is a contribution to the explanation of the behaviour of nickel-iron alloys containing 35–99 per cent. of nickel, as dependent on composition and heat-treatment.

Measurements of magnetic crystal anisotropy and of magnetostriction were made as a function of temperature of cooling. The results confirmed that there is a large effect of cooling rate on anisotropy in the region near Ni_3Fe, but the tests show a substantial effect also in alloys containing between 50 and 85 per cent. nickel. Two magnetostriction constants, λ_{100} and λ_{111}, were measured on the same crystals: the effect of cooling rate on magnetostriction was found to be substantial only in the composition range 70–80 per cent. nickel. The principal changes in magnetic properties as a function of composition are explained in terms of the crystal anisotropy and magnetostriction, and their change with variation in heat-treatment.

S. KAYA: 'Uniaxial Anisotropy of a Permalloy Crystal.' pp. 49–53; disc. pp. 53–5.

When alloys containing nickel 76, iron 24, per cent. are annealed at 490°C. after quenching from 600°C. the energy content decreases with time of annealing,

not monotonically, but in two steps. By direct measurement of the time-rate of energy decrease, it was concluded that the first step is connected with formation of short-range order and the second with that of long-range order. The effect of a magnetic field applied during cooling, on maximum permeability, is associated mainly with formation of short-range order.

D. I. GORDON: 'An Experimental Study of Barkhausen Noise in Nickel–Iron Alloys.' pp. 56–7.

The experiments described were made in the U.S. Naval Ordnance Laboratory, as a part of the programme for development of improved magnetic materials for military and industrial applications. Curves show (1) variation of magnetic noise with composition and heat-treatment, in binary iron–nickel alloys, and (2) magnetic noise as a function of magnetic permeability in nickel–iron alloys containing 4 or 5 per cent. of molybdenum. The research is stated to have resulted in development of a high-permeability core material characterized by minimum Barkhausen noise.

G. T. RADO: 'Magnetic Spectra of Ferrites.' pp. 81–9.

Includes reference to nickel-containing ferrites.

H. J. P. WIJN, M. GEVERS and C. M. VAN DER BURGT: 'Note on the High-Frequency Dispersion in Nickel–Zinc Ferrites.' pp. 91–2.

Report of experiments on ferrites of the Ferroxcube type.

H. J. P. WIJN and H. VAN DER HEIDE: 'A Richter-Type After-Effect in Ferrites containing Ferrous and Ferric Ions.' pp. 98–9.

Includes data on manganese–zinc and nickel–zinc ferrites.

J. E. GOLDMAN: 'Atomic Moments in Alloys.' pp.108–13; disc., p. 113.

The saturation moment of ferromagnetic alloys is considered from the point of view of the collective electron theory. The paper includes observations on copper-rich nickel–copper alloys, nickel–manganese alloys of Ni_3Mn type, and nickel–iron alloys.

J. M. HASTINGS and L. M. CORLISS: 'Neutron Diffraction Studies of Zinc Ferrite and Nickel Ferrite.' pp. 114–19; disc., pp. 119–21.

W. P. MASON: 'Rotational Relaxation in Nickel at High Frequencies.' pp. 136–9.

Measurements of the ΔE effect and the decrement, by various investigators, are compared with values expected from a calculation of domain wall relaxations for a distribution of domain sizes, as determined by optical measurements.

S. LEVY: 'Ultrasonic Attenuation in Magnetic Single Crystals.' pp. 140–5.

A striking relationship was found between the magnetic properties and the ultrasonic attenuation properties of a nickel single crystal. Magnetic anisotropy was detected by measuring the attenuation as a function of applied intensity. Information on the vibrations of Bloch walls and the number of vibrating walls per unit length was also obtained. Comparative measurements were made on a 3·8 per cent. silicon silicon-iron alloy.

E. M. PUGH and N. ROSTOKER: 'Hall Effect in Ferromagnetic Materials.' pp. 151–7.

Experimental results are reviewed for iron, cobalt, nickel, and the cobalt–nickel and nickel–copper alloy series. Most of the measurements were made at room temperature, but for nickel the data cover the range 10° to 800°K. (−263° to +527°C.)

E. P. WOHLFARTH: 'The Theoretical and Experimental Status of the Collective Electron Theory of Ferromagnetism.' pp. 211–19.

This paper is intended to supplement review articles published by Stoner in 1948 and 1951, firstly by considering in greater detail the quantum-mechanical and statistical-mechanical foundations of the collective electron theory, and secondly by considering briefly a wider range of relevant experimental results. The experimental data recorded include (1) variation, with composition, of the Curie temperature and saturation magnetization; (2) variation, with temperature, of the magnetic susceptibility of nickel alloys; (3) variation, with temperature, of the magnetization, electronic heat, and magnetocaloric effect of cubic cobalt, nickel, and nickel alloys below the Curie point; (4) high-temperature electronic heats of nickel and of palladium; (5) electronic properties of chromium and some other transition metals, and (6) electronic properties of palladium and its alloys.

E. C. CRITTENDEN and R. W. HOFFMAN: 'Thin Films of Ferromagnetic Materials.' pp. 310–15; disc., p. 315.

Experimental observations on the magnetic properties of thin evaporated films of nickel are reported. Surface roughness of the films was carefully controlled. The specimens behaved in a way which indicates that surface variations extend into the film approximately 3 Å from each surface.

A. H. GEISLER: 'Coercive Force of Precipitation (Hardening) Alloys.' pp. 316–22.

Three of the commercial types of permanent-magnet alloys, nickel–aluminium–cobalt–iron (Alnico), copper–nickel–cobalt (Cunico) and copper–nickel–iron (Cunife) are cubic solid solutions which decompose, during the ageing heat-treatment, into two cubic phases of slightly different lattice parameters. The prototype of these alloys is the nickel–gold system, which is used by the author in describing the characteristics of this class of material. During precipitation heat-treatment saturation-magnetization and remanence increase as the ferromagnetic nickel precipitate forms: coercive force first increases and then decreases. At the condition of high coercive force the decomposition products are coherent with each other,

and thus have tetragonal crystal structure instead of cubic structure.

As a result of the experiments recorded in this paper, the author has derived a single empirical relation in which maximum coercive force is directly related to degree of tetragonality and saturation induction of the precipitate. On the basis of the fine-particle theory, this result suggests that not only shape anisotropy, but also crystal anisotropy, as affected by strain, contributes to the coercive force. This work represents the first successful attempt to correlate the coercive force of the various commercial permanent-magnet alloys with their more fundamental characteristics.

E. A. NESBITT and R. D. HEIDENREICH: 'The Physical and Magnetic Structure of the Mishima Alloys.' pp. 322–3.

Observations of structure in a (100) single crystal of approximately Fe_2NiAl composition are correlated with structures found in Alnico V, in which a new face-centred cubic precipitate has been found. Examination of the Fe_2NiAl alloy in various conditions indicates that values of anisotropy existing in this alloy are sufficient to account for all the measured values of coercive force, on the basis of the crystalline anisotropy of the precipitate and of the matrix.

Nickel-containing Materials having Special Magnetic Properties

G. H. STEARLEY: 'Magnetic Materials.' *Materials and Methods*, 1953, vol. 37, Apr., pp. 115–30. *Materials and Methods Manual No.* 93.

This is one of the regular series of summary reviews of the compositions, properties and uses of materials of various types, which are a characteristic feature of this journal.

Materials showing special magnetic properties are considered in four groups:—

(1) *Non-retentive, or soft, magnetic materials*, e.g., high-purity iron, and silicon-iron, nickel-iron-base, cobalt-iron, nickel-cobalt-iron, and related alloys.

(2) *Permanent or hard magnetic materials*, including the older permanent-magnet steels, the newer alloys of the Alnico (nickel-aluminium-cobalt-iron-base), copper-nickel-iron, copper-nickel-cobalt, cobalt-iron-vanadium types, and oxide magnets.

(3) *Magnetic materials having special properties*, e.g. (*a*) alloys having high induction values, (*b*) alloys showing specially constant permeability, e.g., 50–50 nickel-iron alloy and nickel-cobalt-iron alloys of the Perminvar type, (*c*) temperature-sensitive alloys of the nickel-copper and nickel-iron types, in which the Curie temperature can be regulated by composition, and (*d*) alloys used for high-frequency applications, e.g., molybdenum-Permalloy and the ferrites, as used for cores.

(4) *Non-magnetic materials*, such as the chromium-nickel austenitic, and high-manganese and nickel-manganese steels, and austenitic nickel-containing cast iron, as used, for example, in applications where high electrical resistance renders such materials suitable for parts in which losses due to flow of eddy currents must be minimized.

For the three groups of magnetic material a condensed survey is made of compositions, properties, treatment, and uses.

The article is well illustrated, and the description of the individual materials is preceded by a useful glossary of magnetic terms.

Magnetostriction Characteristics of Alnico V Alloy

J. R. IRELAND: 'Magnetostriction in Alnico V.' *Electronics*, 1953, vol. 26, May, pp. 234, 236.

This note describes an investigation of the effects of production processes on the magnetic and magnetostrictive properties of a nickel-aluminium-cobalt-iron alloy: the work was done in connexion with development of Alnico V magnets for use in vibration pick-ups operating on magnetostrictive principles.

Alnico V is normally heated at approximately 1650°F. (900°C.) and cooled at a controlled rate in a strong magnetic field, the direction of this field being that in which final magnetization of the material is to be performed. After such treatment the material is tempered for 5 hours at about 1090°F. (585°C.). Such thermomagnetic treatment produces high magnetic properties in the direction of orientation, with lower properties in all other directions. Since it was believed that the orienting treatment had an effect of magnetostriction, this aspect was studied, with the results summarized below.

Several heats of the alloy were used and samples from each were run through identical treatments. Three variations of orienting procedure were used: the first group of samples was oriented in the normal manner, parallel to the cylindrical axis of the bar; a second group was oriented at right angles, across the diameter of the bar, and a third group was put through the normal heat-treatment, but cooled without application of a magnetic field. All samples were then tested, tempered, and re-tested.

The results showed that inherent magnetic properties, as indicated by flux values, bear little or no relation to magnetostrictive properties. Best magnetostrictive properties are obtained by heat-treating the material and allowing it to cool without application of a magnetic field. If a slightly higher coercive force is desired it may be obtained by tempering, but such treatment will somewhat lower the magnetostrictive properties. This method, introduced in production of magnets used in the vibration pick-ups, has eliminated many of the unpredictable variations in magnetostrictive properties previously experienced in magnets which had been subjected to the usual thermomagnetic treatment.

Properties of Invar: Theoretical Discussion

Y. TINO: 'On the Invar Problem.' *Jnl. Scientific Research Inst.*, Tokyo, 1952, vol. 46, pp. 141–6.

Theories which have been advanced to explain the occurrence of the low coefficient of expansion characteristic of the 36 per cent. nickel nickel-iron alloy are discussed, and a new theory is proposed. This attributes the phenomenon of low expansibility to the presence of dispersed α-phase globules in the γ matrix of the alloy.

CAST IRON

Machinability Tests on Plain and Low-Alloy Cast Irons

E. A. LORIA: 'Which Gray Irons for Large Volume Productions?' *Iron Age*, 1953, vol. 171, Apr. 9, pp. 131–3.

Report of tests on low- and high-phosphorus cast irons, in which phosphorus above the normal level proved to have a beneficial influence on machinability. In unalloyed cast irons treatment with silicon carbide produced microstructures exhibiting the best machining characteristics: in the alloy cast iron series the beneficial influence of nickel was confirmed. Chromium–molybdenum cast irons were the least machinable of the types examined, due to their carbide-forming tendency. In both the unalloyed and the alloyed groups, microstructure could be closely correlated with machining characteristics.

Ni-Hard in Clay-Working Machines and Gravel Pumps

'Wear-Resistant Iron Adds Life to Clay-Working Machines.' *Nickel Topics*, 1953, vol. 6, No. 4, p. 6. 'Ni-Hard Gravel Pumps.' *ibid.*, p.7.

The Stevenson Company of Wellsville, Ohio, specializes in the manufacture of clay-working machinery of all kinds, including roll crushers, master grinders, grinding pans, extrusion dies, refractory shape presses, and conveying equipment. Muller tyres play a major part in the operation of clay-grinding equipment and are subjected in service to extreme wear conditions. For these parts nickel–chromium cast iron of the Ni-Hard type has proved to give the best performance, and the same material is being used for many other components subject to abrasion and wear. The Stevenson Company states that its records on Ni-Hard show an average life 4–6 times longer than that obtained with ordinary cast iron, and in some instances Ni-Hard scraper heels have given 16 times the life of heels of plain cast iron. All the Ni-Hard castings used in the clay-working machinery are stress-relief annealed, to provide maximum resistance to shock, without sacrifice of hardness and abrasion-resistance.

A further application for which Ni-Hard is being used with outstanding success is that of pumps handling sand and gravel. Liners and other parts made from this material have given such markedly increased life as to lead to their employment by a number of gravel producers in the Southern Alabama region, where a large deposit of high-grade gravel is being worked.

Data Sheet on S.G. Iron

MOND NICKEL CO., LTD.: 'Spheroidal-Graphite Cast Iron.'* *Publn.* 637, 1953; 4 pp.

This publication comprises concise information on the essential character of magnesium-treated cast iron, in which, by change of graphite form from flake to spheroidal, the strength of the iron is doubled and a good degree of toughness is developed. The notes are accompanied by detailed tables showing (1) properties of cast and annealed S.G. iron, compared with those of high-duty flake-graphite cast iron, and (2) comparative properties of some alloyed cast irons in which the graphite is present (a) in flake, or (b) in spheroidal form.

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Heat-Treatment and Properties of S.G. Iron

J. H. BARNETT: 'Heat-Treatment of Nodular Cast Irons.' *Colorado School of Mines Quarterly*, 1952, vol. 47, No. 1; abstract in *Metal Treatment*, 1953, vol. 20, Mar., p. 102.

This paper reports a study of heat-treatment of S.G. iron, carried out with the object of (1) determining the effect of soaking time and quenching temperature, on microstructure, combined-carbon content, and hardness, and (2) ascertaining whether cast irons treated with different 'nodulizing' media behave in the same manner when quenched from a given temperature.

From the results obtained, the author draws the following conclusions: (1) Nodular iron has good properties in the as-cast condition, and these properties can be still further improved by suitable heat-treatment. It is a versatile material, the characteristics of which can be controlled in such a way as to render it capable of meeting a number of different requirements. (2) Cementite in nodular iron decomposes at temperatures commonly used in the annealing of malleable iron, but it forms tiny spheroids of graphite instead of flake or temper graphite. (3) Final traces of pearlite in nodular-iron microstructures are relatively persistent, and are broken down only after exposure to high temperatures for long periods of time. (4) Magnesium–nickel-treated irons are hardenable to such a degree that their use in wear-resistant applications appears feasible. (5) Pearlite in the matrix of nodular cast irons may be removed by holding the iron at subcritical temperatures, as in the second-stage annealing of malleable cast iron. (6) In the magnesium–nickel-treated iron investigated, the temperature required to produce, in quenched specimens, the microstructure to be expected after tempering is above 1000°F. (540°C.) when tempering periods of three hours or less are used.

Review of Current Industrial Applications of S.G. Iron

'Nodular Iron Tackles Big Jobs.' *Steel*, 1953, vol. 132, Mar. 16, pp. 102–4.

This article is based on a review, made by T. E. Eagan, of recent progress of S.G. iron, with particular reference to the activities of Cooper-Bessemer Corporation, which in 1952 produced 900 tons of S.G. iron castings, mainly in large size and heavy section, for use in compressors, and in diesel and gas engines.

Metallurgical control for commercial production has now been well established, and the properties required for various engineering applications are consistently developed. S.G. iron exhibits a true stress–strain curve; gives a high, constant modulus of elasticity (25 million p.s.i.), and fatigue-resistance comparable

with that of ordinary grades of steel, both in the notched and the un-notched conditions. These properties make the material ideal for crankshafts, generator shafts, connecting rods, camshafts, and other types of equipment subject to alternating stresses and bearing wear.

S.G. iron has a particularly high yield point, which is an important feature in determining load-carrying ability. Tests have shown that it exhibits good resistance to mechanical wear, both lubricated and unlubricated. Use of S.G. iron in engine parts is steadily increasing: this type of material promises to be of special value in the cylinder heads, pistons, and liners of high-output engines.

Engineering Applications of S.G. Iron

B. L. STOTT: 'Ductile Iron as an Engineering Material.' *Soc. Automotive Engineers*, Preprint 16, Jan., 1953; 3 pp.+many figures.

This paper is devoted mainly to illustrating applications of S.G. iron in the automobile, agricultural, and other engineering fields. Average properties of S.G. iron produced by the foundry with which the author is associated are given:—

As-cast: tensile 45 tons per sq. in.; yield 29·5 tons per sq. in.; elongation 6·25 per cent.; Brinell hardness 241.

Annealed: tensile 30 tons per sq. in.; yield 23 tons per sq.in.; elongation 21 per cent.; Brinell hardness 170.

The following applications are mentioned as typical of those for which S.G. iron castings have proved successful:

liners for cement pumps, in which S.G. iron has given twice the life of hardened steel;

shell-heading dies, where hardened S.G. iron gave a life of 875,000 shells as compared with 45,000–60,000 shells for tool-steel dies. The cost of the S.G. iron die is only half that of the tool-steel die;

trenching-machine sprockets, differentially hardened on the teeth to 60 Rockwell C, with the hubs left machinable;

main drive pinions for drag lines. In this case 3 per cent. of nickel was specified, to facilitate heat-treatment;

chains and sprockets used in handling hot billets in steel mills, where S.G. iron has resisted far better than steel the wear caused by mill scale;

furnace doors, where S.G. iron shows much increased life as compared with doors of ordinary cast iron.

S.G. Iron in Agricultural Machinery

R. W. MASON: 'Irons with Spheroidal Graphite.' *Soc. Automotive Engineers*, Preprint 15, Jan., 1953, 4 pp.

The author describes development work in an American foundry producing a large number of small light castings for agricultural machines, in which harder, stronger and more wear-resistant material than ordinary cast iron is required, with increased ductility and toughness. Many grades of S.G. iron are in regular production.

For a number of parts previously made as steel castings S.G. iron is now being successfully used: items discussed in this paper include spindles for grain-drill disc openers, corn-planter shoes, gears, and clutches. First results on S.G. iron ploughshares are reported as excellent, as were also trials on cultivator shoes.

CONSTRUCTIONAL STEELS

Austenite-Martensite Transformation in Iron-Nickel-Manganese Alloy

R. E. CECH and J. H. HOLLOMON: 'Rate of Formation of Isothermal Martensite in Fe-Ni-Mn Alloy.' *Jnl. of Metals*, 1953, vol. 5, May, Sect. 2; *Trans. Amer. Inst. Mining and Metallurgical Engineers*, pp. 685–9; T.P. 3463E.

The paper describes results obtained in studies of isothermal transformations, over the range −79° to −196°C., in an alloy of the following composition: iron 73·3, nickel 23·0, manganese 3·7, per cent. The following characteristics were observed:

'Isothermal transformation of martensite was observed at all the temperatures used: −79°, −90°, −100°, −120°, −125°, −128°, −140°, −150°, −159°, −196°C. Rate of formation increased with lowering of temperature, to a maximum at −128°C., and subsequently decreased with further lowering of temperature.

'Formation of martensite can be suppressed completely in this alloy by rapid quenching below room temperature.

'Partial stabilization can be brought about by ageing at room temperature, either prior to sub-cooling or after some isothermal transformation.

'Isothermal transformation proceeds by delayed formation of martensite nuclei followed by rapid growth to full-size martensite platelets.'

Continuous-Cooling Transformation Diagrams for Nickel-Alloy Steels

W. STEVEN and G. MAYER: 'Continuous-Cooling Transformation Diagrams of Steels.' *Jnl. Iron and Steel Inst.*, 1953, vol. 174, May, pp. 33–45.

Isothermal transformation diagrams are of value for many research purposes, and as a basis for some special heat-treatments, but the information which they provide is not readily applicable to heat-treatments involving transformation under continuous-cooling conditions. Since most commercial heat-treatments fall into this category a need exists for diagrams which will portray the transformations that occur in steel during continuous cooling from an austenitizing temperature, as clearly as an isothermal diagram shows the progress of transformations at constant temperatures. The work described in this paper is a contribution towards meeting this requirement.

After a brief review of the relevant literature, the authors describe a method (developed in the laboratories of The Mond Nickel Company, Ltd.) for the determination of continuous-cooling transformation

diagrams, portraying the course of transformation with temperature in bars up to 6 in. diameter, when quenched in oil under standard conditions. Diagrams obtained by this method are presented for the following types of steel:—

En No.	Type of Steel
12	1 per cent. nickel
16	Low-alloy manganese-molybdenum (1·3–1·8/0·2–0·35 per cent.)
17	Higher-molybdenum manganese-molybdenum (1·3–1·8/0·35–0·55 per cent.)
19	1 per cent. chromium-molybdenum
23	3 per cent. nickel-chromium
26	2½ per cent. nickel-chromium-molybdenum (high-carbon)
111	Low-nickel-chromium steel (1·0–1·5/0·45–0·75 per cent.)
160	2 per cent. nickel-molybdenum

Closely parallel isothermal transformation diagrams are presented for the En 12 and 19 steels.

Information derived from isothermal transformation diagrams of oil-quenched bars and from end-quench hardenability curves is compared with that provided by the continuous-cooling transformation diagrams.

Machinability of Cast Steels

N. ZLATIN, J. F. KAHLES and C. W. BRIGGS: 'The Machinability of Cast Steels.'
Reprint from Tool Engineer, Feb., 1953 ; issued by International Nickel Co., Inc.; 11 pp.

This article is based on Research Report No. 27, published by the Steel Founders' Company of America: it summarizes results of an investigation carried out by Metcut Research Associates, Cincinnati, Ohio.

Tests were made on cast steel bar of the following S.A.E. types: medium-manganese (1330); chromium-molybdenum (4130); nickel-chromium-molybdenum (4340 and 8630); manganese-molybdenum (8430). Both carbide and high-speed steel tools were employed, and standardized cutting conditions were maintained, using various speeds. Full details are given of test conditions, and the design of the tools used is illustrated.

Curves of tool life *vs.* cutting speed are given, as relating to machining of the steels in various conditions, with both types of tool. Practical recommendations are made with regard to application of these data to industrial machining operations, and methods of estimating power requirements under given conditions are described.

The data obtained lead to the conclusion that microstructure has a definite effect on the machinability of cast steels. In some cases it is possible to improve machining characteristics as much as 100–200 per cent. by heat-treatments which alter the microstructure: particulars are given of the treatments optimum for each type of steel. The observations on the nickel-alloy steels are summarized below:—

The 4340 nickel-chromium-molybdenum steel was given four separate heat-treatments: normalized and annealed, normalized and spheroidized, quenched-and-tempered to 300 Brinell hardness, and quenched-and-tempered to 400 Brinell hardness. With carbide tools the spheroidized steel showed the best machining qualities: in this form it can be machined 65 per cent. faster than the same material in the annealed condition. In the quenched-and-tempered condition (at both hardnesses) the steel machines poorly. At very low speeds the quenched-and-tempered steels have similar machinability, but at higher speeds the softer steel machines the more easily of the two. Although the hardnesses of the spheroidized steel (Brinell 210) and the annealed steel (Brinell 200) are closely similar, the former has markedly superior machining qualities. When using high-speed steel tools machinability of the 4340 steel improved with increasing hardness, with the exception that the spheroidized condition was more favourable than the annealed state.

In the 8630 low-alloy nickel-chromium-molybdenum steel the annealed material (50 per cent. ferrite, 50 per cent. pearlite) machined considerably better than the steel in the normalized condition: with carbide tools the former could be cut at a speed 65 per cent. greater than that practicable for the latter. The annealed steel (175 Brinell) could be machined, with high-speed tool steels, at a much higher rate than the normalized steel (Brinell 240).

The skin* of all the cast steels showed poor machinability, and it is recommended that, to obtain equivalent tool life, the skin of a cast steel should be machined at approximately one-half of the cutting speed recommended for the base metal.

American Iron and Steel Institute Constructional-Steel Specifications

'Boron and Tentative Standard Steels.' *Metal Progress*, 1953, vol. 63, Apr., p. 96B.

The list gives compositions of steels in the above categories, current as of February, 1953. The grades covered include many low-nickel alloy steels.

Dilatation Tests for Assessment of Weldability

C. L. M. COTTRELL: 'Assessment of Weldability by Rapid Dilatation Tests.' *Jnl. Iron and Steel Inst.*, 1953, vol. 174, May, pp. 17–24.

It has been shown by various investigators that the greater the hardness value produced in the heat-affected zone adjacent to metallic-arc welds, the more likely are hard-zone cracks to occur. This observation has been amplified to show that the rate of cooling at 300°C. in the hard zone is important. A theory put forward by HOPKIN (*Trans. Inst. Welding*, 1944, vol. 7, pp. 76–8) indicated the importance of hydrogen dissolved in the weld metal, as affecting the formation of

* Peripheral section of bar to ¼in. beneath the surface.

these cracks. Work by WHEELER and KONDIC (*Symposium on Metallurgy of Steel Welding*, pp. 71–83) has shown that when a steel is heated to a high temperature and subsequently quenched, a martensite having inferior mechanical properties is produced. The results obtained by several investigators have suggested that the effect of hydrogen during the austenite–martensite transformation should be an important factor in the initiation of cracks in the hard zone. The present paper reports determination of the relationship between the temperature at which the austenite–martensite transformation occurs in certain alloy steels and the liability of these steels to cracking.

The steels used were of the nickel–chromium–molybdenum type, having three levels of manganese, nickel, and chromium, giving a series of 27 steels. In addition, four steels containing copper, four with zero (residual) nickel, and a commercial boron–molybdenum steel which had shown good weldability, were tested. The results of weldability tests on all the steels (previously published by BALL and COTTRELL: *Jnl. Iron and Steel Inst.*, 1951, vol. 169, pp. 321–36), are reproduced in the present paper, for purposes of correlation.

The results of the author's tests show that, for a given set of welding conditions, the presence of cracks in the hard zone, for the series of steels used, is related to the temperature at which austenite transformation is completed during cooling. When transformation is completed above 290°C. cracking is absent, but when transformation continues below that temperature cracks occur. This relationship explains the importance of rate of cooling at 300°C. in relation to hard-zone cracking. When welding a particular steel with a rutile electrode, a given cooling cycle may produce hard-zone cracks when transformation is completed below 290°C. By maintaining the same cooling rate at high temperatures and retarding the cooling rate in the region of 300°C. transformation will be completed above 290°C., and hard-zone cracks should be absent.

Consideration of the effect of the individual alloying elements on the temperature of completion of transformation indicates that nickel contents up to 1·0 per cent. should not greatly affect the weldability of steels of this type, and that chromium contents of 0·6–1·0 per cent. should also have little effect. Additions of manganese, however, in all amounts, adversely affect weldability. These indications are in agreement with results of previous work on the metal-arc welding of such steels.

The experimental technique by which the thermal cycle occurring in the heat-affected zone of a weld is simulated in a dilatometer specimen is described, and the dilatometric equipment is illustrated. This rapid test can be used for assessing the weldability of low-alloy steels, without making a welding test.

HEAT- AND CORROSION-RESISTING ALLOYS

Creep Tests on Nimonic Alloys under Cyclic Stress and Temperature Conditions

D. C. HERBERT and D. J. ARMSTRONG: 'Creep Tests on Nimonic Alloys under Varying Stress and Temperature.' *Engineering*, 1953, vol. 175, May 8, pp. 605–6.

Turbines are frequently required to operate at specified levels of power for certain periods, with correspondingly different conditions of stress and temperatures. In some cases the cycle is repeated daily. In the design of gas-turbine blades this factor may be important, but little information has yet been published regarding the effect of changes of stress or temperature on creep rates and fracture characteristics. The work reported in this paper was carried out at the National Physical Laboratory to provide some relevant data on two typical gas-turbine blade materials, Nimonic 80A and Nimonic 90.

In the cycle selected, two levels of operation were used, the stress at the lower level being 90 per cent. of that at the higher one, and the temperatures being 780° and 640°C. respectively. The compositions of the two alloys tested were as under:—

Alloy	C %	Si %	Mn %	Cr %	Ti %	Al %	Cu %	Fe %	Co %	Ni %
Nimonic 80A ...	0·082	0·33		20·1	2·48	0·56		0·11		76·3
Nimonic 90 ...	0·07	0·48	0·13	19·40	2·56	1·54	0·10	0·38	19·10	bal.

Both materials were in the form of $\frac{5}{8}$–in. diameter bar and had been heated for 8 hours at 1080°C., air-cooled, re-heated for 16 hours at 700°C. and air-cooled.

The tests were made in N.P.L.–pattern 2–ton tensile creep machines; details are given of means used for cycling the test conditions. For both materials the high-level conditions were 780°C. and 10·8 tons per square inch for 6 hours and the low-level conditions 640°C. and 9·7 tons per square inch for 18 hours, the cycle being repeated every 24 hours. Comparative tests were also made, under constant conditions, at 780°C. and 10·8 tons per square inch. An additional series of determinations on Nimonic 90 involved a stress of 15 tons per square inch, reduced to 13·5 tons per square inch for the low-level value: temperatures and time intervals were as in the earlier tests. A constant test was again made at the high stress level, for comparison. All the tests were continued to fracture, and observations of strain were recorded at intervals, which were frequent except when operating at low levels. Creep recovery was minimized by cooling the specimen before reducing the load in each cycle.

The results of all the tests are presented in tables and curves. Examination of the tertiary part of the creep curves shows that creep rates were greater in the periodic than in the constant tests, but that final fracture occurred at about the same times in both periodic and continuous tests, and that final elongations were

similar. It is clear from the observations made that the effect of the cycles used in this investigation could be assessed approximately by considering solely times at the high-level conditions, since times at the low levels played only a small part, and could be regarded as rest periods. The authors consider, however, that it is unjustifiable entirely to ignore the periodic nature of the loading, since there was some tendency for the creep strain to be greater than would have been the case if no rest periods had occurred.

Machining of the Nimonic Alloys

HENRY WIGGIN AND CO., LTD.: 'Notes on Machining the Nimonic Series of Alloys.'
Publn. 343*B*,* 1953; 29 pp.

This edition is a revision of Publication 343A. It embodies additional information on drilling, and the list of suppliers of tools and lubricants suitable for use with the Nimonic alloys has been revised. The text has been modified, and amplified to include recommendations on machining of Nimonic 90 and 95, as well as the alloys covered by the earlier editions.

High-Temperature Properties of 18–8–Mo Steel

G. J. GUARNIERI: 'High-Temperature Testing of Type 316 Stainless Steel Sheet.' *U.S. Atomic Energy Commission Report AECU*–1936: Abstract in *Metal Progress*, 1953, vol. 63, Apr., pp. 184, 186, 188.

Report of investigation of the creep and stress-rupture properties of molybdenum-containing 18–8 chromium–nickel steel sheet, in the annealed and the as-welded conditions. The sheet used was 0·062-in. thick; it was heated at 2000°F. (1093°C.) for 30 minutes, and air-cooled, a treatment which gave a fully austenitic structure and an A.S.T.M. grain size of 2–4.

Creep and stress-rupture determinations were made at 1200°, 1400°, 1500°, 1600° and 1800°F. (648°, 760°, 815°, 870° and 980°C.). Results are presented in tabular form, and time-deformation creep curves and time-stress curves are given (in the original, *not* in the abstract).

Marked strain-hardening was found to occur at 1200°F. (648°C.), with the result that stresses well above the yield strength were required to produce fracture in 1000 hours. As the temperature was raised the strain-hardening lessened, until at 1800°F. (980°C.) it was non-existent. There was some loss in rupture strength in the welded material; this was most pronounced at 1800°F. In all the tests fracture was in the weld deposit: it is considered that by careful selection of filler rods, higher strengths could be attained for the weld metal. Fractures at 1200°F. were transgranular; at 1500°F. some intergranular failure was noted, and at 1800°F. the fractures were predominantly intergranular.

The photomicrographs in the original report show the microstructural changes resulting from exposure at the various temperatures of test: sigma and some carbide were the predominant constituents formed from the parent austenite. Transformation to sigma was sluggish at 1200°F., but as the temperature was raised up to 1500°F. there was gradual increase in the amount of sigma formed. Above that temperature sigma formation decreased, and there was no transformation to sigma at 1800°F. Formation of sigma was, as would be anticipated, associated with increase in hardness and fall in room-temperature ductility, but the deterioration in ductility at room temperature was not prohibitive. The stress-rupture data indicate that reasonable hot-ductility may be expected in the Type 316 steel at the temperatures used in these tests. Ductility at fracture decreases on long exposure at 1800°F., due to marked intergranular deterioration, as well as to excessive general surface oxidation.

On the basis of these investigations, the author states that in the design of structural components in this type of steel 1600°F. (870°C.) would be recommended as a conservative maximum temperature limit. Where only short life expectancy would be adequate, a peak temperature of 1800°F. (980°C.) could be tolerated with stresses below 1,000 p.s.i.

Radiation-Suppressing Coatings for Nickel-containing High-Temperature Alloys

A. H. SULLY, E. A. BRANDES and R. B. WATERHOUSE: 'Radiation-Suppressing Coatings for Metals at Elevated Temperatures.' *Fulmer Research Inst. Special Report*, No. 1, Apr., 1953; 24 pp.
See also *Times Rev. Industry*, 1953, vol. 7, June, p. 38.

The authors point out that for the flame tubes of gas turbines it would be an advantage to use materials characterized by an emissivity which decreases with rising temperature. In this report results are given of the emissivity of various materials as a function of temperature: nickel-chromium-base alloys of Nimonic types and austenitic nickel-chromium steels were included in the survey. The investigation covered, *inter alia*, a study of the influence of surface condition (shot-blasted, buffed, and as-rolled) on emissivity, and it was observed that roughening of surfaces greatly increases emissivity in the unoxidized condition. This difference persisted, although to a lessening extent, with increasing oxidation, at temperatures up to 900°C. Although polished surfaces would thus be much more efficient in reducing radiant heat transfer, in such components as flame tubes, metallic materials still show increased emissivity with rise of temperature, and they are also subject to risk of an irreversible increase due to increased oxidation caused by a short period of overheating.

The emissivity of pure refractory substances, on the contrary, decreases with rise in temperature, and the authors urge the advantage of coating of metallic parts with suitable refractories. Emissivity of typical refractories at high temperatures is recorded. Development of a practical means of applying protective coatings of this type is, however, complicated by the service conditions in which the parts operate (including cycling of temperature, which involves severe thermal shock). The low mechanical strength of refractories is a further disadvantage.

Direct sintering of refractory coatings onto the metallic materials is impracticable, due to the high temperatures which would be involved, and the authors recommend, as an alternative, the use of an

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undercoat of a suitable bonding enamel to secure attachment of the coating. Experimental data on enamel-bonded, refractory-coated specimens are reported. The results of laboratory tests suggest that this compromise method is suitable for use on metallic parts designed to operate at 600°–900°C., but it is considered that the refractory coatings are unlikely to afford any protection against attack by vanadium or lead compounds, which constitutes one of the major problems involved in development of gas turbines using heavy fuel oils.

Strain-Induced Martensite Transformation in Austenitic Nickel-Chromium Steel

C. D. STARR: 'Notes on the Plastic Critical Temperature in Strain-Induced Martensite Reactions.' *Jnl. of Metals*, 1953, vol. 5, May, Sect. 1; *Trans. Amer. Inst. Mining and Metallurgical Engineers*, p. 654; T.N. 153E.

Martensite transformation can be induced to occur isothermally above the M_s temperature by plastic deformation of an alloy in an austenitic condition. As the test temperature is raised above the M_s point plastic deformation under a given set of conditions merely causes additional slip, with a corresponding tendency towards formation of less martensite per unit of strain. It thus appears that there is a maximum temperature above which martensite cannot be formed isothermally by plastic deformation. This temperature is commonly designated as the equilibrium temperature T_E.

Attempts to determine experimentally the equilibrium temperature have indicated that, under a given set of conditions, a critical temperature is observed above which martensite cannot be formed by plastic deformation. The observation of the so-called 'critical temperature, T_D' is not, however, to be confused with the equilibrium temperature, T_E.

In order to clarify this anomaly, true stress–strain curves were obtained by the present author for a series of 18–8 chromium–nickel steels, over the range 67° to 300°K. (−206° to +27°C.). Since martensite is magnetic, the amount produced by plastic deformation was measured by determining magnetic permeability as a function of strain. The results of the tests (shown in curves in the original) appear to indicate that a plastic critical point exists at about 240°K. (−33°C.) for this type of steel, but it is evident that 240°K. is not the equilibrium temperature nor even a true plastic critical temperature, since permeability of the material increases with cold rolling at 293°K. (20°C.). It is therefore concluded that the observation of a so-called plastic critical temperature is dependent on the mode of deformation, and has no theoretical significance.

Hardening of Austenitic Chromium-Nickel Steels at 475°C.

B. CINA and J. D. LAVENDER: 'The 475°C. Hardening Characteristics of Some High-Alloy Steels and Chromium-Irons.' *Jnl. Iron and Steel Inst.*, 1953, vol. 174, June, pp. 97-107.

During recent investigations of sigma formation in duplex 18–8–3 chromium–nickel–molybdenum steels stabilized with titanium or niobium it was observed that in the hardness/reheating-temperature curve an unexpected increase in hardness occurred at the lower temperatures. This was tentatively attributed to the precipitation of titanium carbide. More recent work, however, revealed what appeared to be a similar phenomenon in the duplex high-alloy valve steel XCR, containing approximately chromium 24, nickel 5, molybdenum 3, per cent., but no carbide-stabilizer. It was thus apparent that the hardening phenomenon, if similar in the two alloys, could not be attributable to the presence of titanium carbide.

The secondary hardening attained a maximum, in the XCR alloy, at about 475°–500°C., and in view of the possibility that the mechanism of hardening involved might be similar to that associated with '475°C. embrittlement' in chromium–iron alloys (believed to be due to sigma formation), an investigation was planned to determine which of the more common types of iron-nickel-chromium alloys exhibited this hardening, and its precise nature and cause.

Ten alloys were selected for study, of which the nominal compositions are given below:—

Chromium–irons: 21 and 30 per cent. chromium
Chromium–nickel–irons: 24–21; 18–8; 18–8–Ti; 18–10–Ti; 18–8–Mo; 18–8–Mo–Ti; 24–5–Mo; 24–5–Mo (low carbon)

Prior to hardening treatment, all the materials except the 21 and 30 per cent. chromium–iron alloys were given a softening treatment of one hour at 1050°C., followed by water-quenching. The 21 per cent. chromium–iron was tested after two prior treatments: (1) ½ hour at 1100°C. + water-quenching; (2) 2 hours at 800°C. + water-quenching, leaving the alloys in the hard and soft conditions, respectively. The 30 per cent. chromium–iron alloy was softened for 2 hours at 800°C., and water-quenched. After these preliminary heat-treatments, the alloys were heated at temperatures within the range 300°–900°C., for one week, one month, or longer, and hardening was studied as a function of time and temperature of treatment. A large amount of experimental data is recorded, including results of mechanical tests, and microscopical and X-ray examination. The following conclusions are drawn:—

'(1) Development of '475°C. embrittlement' has been confirmed in 21 per cent. and 30 per cent. chromium–irons and has also been observed in duplex alloys of the 24–5–Mo, 18–8–Mo–Ti, 18–8–Mo and 18–8–Ti types. It was not observed in fully austenitic alloys of the 18–8 and 18–10–Ti types, although there was a suggestion of its presence in a 24–21 alloy.

'(2) The phenomenon has been shown to be accompanied by a hardening process, the latter being observed at temperatures in the ranges 375°–525°C. and 350°–525°C. for the fully ferritic and duplex alloys, respectively. Maximum effects were found at 475°–500°C. for the periods investigated.

'(3) A limited number of mechanical tests confirmed the expected increase in tensile strength and the decrease in ductility and impact strength associated with ageing at these temperatures.

'(4) Resistivity and magnetic measurements and X-ray results did not reveal any stresses in the matrix

accompanying the ageing process, but the first two techniques did indicate a continuous change (alloy depletion) in the composition of the matrix. Although this could be attributed to the segregation of chromium from the matrix to form a second phase, no such phase could be detected.

'(5) The extent of secondary hardening was observed to increase with the percentage of δ-ferrite present in the duplex alloys, and with the percentage of chromium content in the fully ferritic alloys.

'(6) X-ray work has shown that σ can form in a 30 per cent. chromium-iron after cold-working by filing and in the duplex 24-5-Mo alloy at as low a temperature as 475°C. and at 550°C. in the 18-8-Mo-Ti alloy.

'(7) The formation of σ at 550°C. and below in all the alloys exhibiting secondary hardening is in accord with theoretical expectations, but an explanation of the hardening in terms of actual precipitation of σ seems to be improbable.

'(8) Further work is required to establish the precise mechanism of 475°C. embrittlement.'

Austenite-Martensite Transformation in Iron-Nickel-Manganese Alloy

See abstract on p. 115.

Oxygen on the Surface of Passive Stainless Steels

H. H. UHLIG and S. S. LORD: 'Amount of Oxygen on the Surface of Passive Stainless Steel.' *Jnl. Electrochemical Soc.*, 1953, vol. 100, May, pp. 216–21.

The property of passivity in stainless steels resides in certain films formed on the surface; the nature of the film depends on the properties of the basis metal. According to a widely accepted theory, the passive film is composed of metal oxides, predominantly chromic oxide, which acts as a diffusion barrier layer between the metal and its environment and is kept in repair by an oxidizing environment. Such films are sufficiently thick to permit of isolating them by chemical means from the underlying metal, and the structure of separated films has been described. According to another theory passivity is ascribed to a chemisorbed film on the alloy surface, which satisfies residual affinities of the metal for its environment, and which makes up a dipole layer with negative charge on the outer surface. The satisfaction of chemical-valence forces plus the dipole layer account for the diminished reactivity of the alloy, in addition to a noble galvanic potential. The important source of passivity, according to this view, is a film of the order of a monolayer in thickness, and, therefore, too thin to be seen or handled. Protagonists of this view consider that thicker oxide films which may form subsequent to formation of the adsorbed film are of secondary importance in the passivation mechanism, and are not a necessary condition of the corrosion-resistance characteristic of the steels.

As a means of deriving clearer evidence for the validity of either of the above theories, the present authors made measurements of the oxygen present on the surface of stainless steels in various conditions, in order to determine the minimum thickness of film required to make the steel corrosion-resistant and to impart to it a noble potential.

The amount of oxygen present on the surface of 18-8 was obtained by pickling the steel in a hydrochloric-sulphuric acid solution, washing with nitrogen-saturated water, and subsequently exposing the metal to water of known dissolved-oxygen content. The decrease in dissolved oxygen after a definite period of exposure was taken as a measure of the oxygen taken up by the surface of the steel.

The authors summarize their observations and conclusions as follows:—

The take-up of oxygen was rapid for the first few minutes, reaching a maximum, after 6 hours, of 1·1 microgram/apparent cm^2 metal surface. After the 6 hours no further oxygen was consumed up to a maximum exposure of 48 hours. Maximum passivity was attained after about 3 hours in aerated water, as shown by measurements of potential. When the same steel was pickled in a nitric-hydrofluoric acid solution, the oxygen consumed was only 0·33 microgram/apparent cm^2 of surface. This smaller value is related to the decreased true surface area of 18-8 steel so pickled (roughness factor = 1·2), as compared with the condition after hydrochloric-sulphuric acid pickling (roughness factor = 4·0).

The maximum amount of oxygen on passive 18-8, based on so-called true surface area, is 0·28 microgram/cm^2, a value equivalent to a supposed Cr_2O_3 film only 17Å thick. An equivalent adsorbed oxygen film, on the other hand, consists, approximately, of 1 layer of atoms, over which a close-packed layer of oxygen molecules is adsorbed. These data, it is pointed out, are not inconsistent with the adsorbed-film theory of passivity. It is therefore urged that the mechanism of passivation by oxygen need not be considered as different from that produced by carbon monoxide in hydrochloric acid saturated with that gas, in which case the adsorption theory has up till now provided the only plausible explanation.

The authors suggest that oxide films isolated from stainless steels by several investigators have been produced by reaction of the adsorbed film with the metal, the reaction being induced by polishing and abrading, presence of halogen ions and water in the stripping solution, or high temperatures. The present authors believe that such oxide films are of secondary importance in accounting for passivity as measured by corrosion-resistance and by a noble potential.

Corrosion- and Heat-Resisting Alloy: Hastelloy F

'Corrosion-Resistant Alloy Combines Heat- and Corrosion-Resistance with Workability.'
Machine Design, 1953, vol. 25, May, pp. 151–2.

This article contains information supplementary to that recorded in *Iron Age*, 1953, vol. 171, Mar. 26, pp. 148–50: see *Nickel Bulletin*, 1953, vol. 26, No. 5, p. 87. The limits of composition given for Hastelloy F confirm that it is a nickel-chromium-iron-base material containing specified amounts of molybdenum, niobium + tantalum, manganese, silicon, tungsten and cobalt: see typical composition in *Nickel Bulletin*, *loc. cit.* The following claims are made with regard to

	Sheet (0·065–in. thick)				Bar Stock (1–in. dia.)	
	Longtl.		Transverse			
	p.s.i.	t.s.i.	p.s.i.	t.s.i.	p.s.i.	t.s.i.
Tensile strength	106,000	47·3	106,000	47·3	108,000–116,000	48·25–51·5
Yield Strength, 0·2% offset	50,900	22·75	49,000	22	48,000–53,000	21·5–23·5
Elongation in 2 in. %	52		52		40–46	
Reduction of Area %					47–54	
Izod Impact* ft.–lb.					58–100	
Hardness Rockwell B			84		89–93	
Brinell					160–180	
Density (g/cm³)					8·2	
Electrical Resistivity (microhm/cm)					112	
Magnetic Permeability at 116 oersted					1·2	
Modulus of Elasticity					29×10^6 p.s.i.	

Coefficient of Thermal Expansion (in./in./°F.)

68– 200°F. (20°– 93°C.)	8·1
68– 600°F. (20°–315°C.)	8·7
68–1000°F. (20°–538°C.)	8·9
68–1400°F. (20°–760°C.)	9·5
68–1800°F. (20°–980°C.)	10·2

$\times 10^{-6}$

* Notched specimens at room temperature. No loss of toughness found by additional tests at −58°F. (−50°C.)

the corrosion–resisting qualities of the alloy:—

Sulphuric acid: Excellent resistance to boiling 10 per cent. solution. Good resistance to air–free sulphuric acid in concentrations up to 30 per cent. and at temperatures up to 176°F. (80°C.). The high chromium content (21–23 per cent.) increases passivity when air or oxidizers are present. Hastelloy F is *not* recommended for use in boiling sulphuric acid in concentrations above 20 per cent.

Phosphoric acid: 70 per cent. concentrations, at boiling point, can be successfully handled: 85 per cent. concentrations corrode the alloy rapidly.

Ferric chloride + 10% *sodium chloride:* Good resistance to pitting.

42% *Magnesium chloride:* Tests under stress in boiling magnesium chloride (a solution frequently used to determine susceptibility to stress–corrosion cracking) caused no cracking after 500 hours' exposure.

Nitric acid: Corrosion rate increases with time under exposure to 65 per cent. boiling nitric acid.

Sea water: Examination, at intervals, of specimens exposed to sea water showed Hastelloy F to give good resistance to pitting, but to be susceptible to under–gasket corrosion. Equipment for use in sea water should be designed to minimize crevices and contact areas which can form regions of low oxygen concentration.

Although few major applications of the new alloy have yet been tested, three years' trial in the top vapour zone of a sulphite digester, in which the cooking liquor contains about 10 per cent. of sulphur dioxide, have proved its suitability for this purpose. Tests so far made indicate that Hastelloy F has a combination of properties ensuring good service in processes involving: (1) weak, strong, or sulphurous acids for the first part of a cycle and an alkaline condition for the final part (starting with pH 4 and ending with pH about 9), and (2) liquid or vapour phases of alkaline or acid pulping digesters, in which (especially in the vapour phase) corrosion of other alloys has been serious.

The mechanical and physical properties in the table above are quoted as typical of Hastelloy F.

Resistance of Stainless Steel to Organic Compounds

I. R. LANE, L. B. GOLDEN and W. L. ACHERMAN: 'Corrosion–Resistance of Titanium, Zirconium, and Stainless Steel in Organic Compounds.'
Industrial and Engineering Chemistry, 1953, vol. 45, May, pp. 1067–70.

Organic compounds are not usually regarded as being so destructive to metals as inorganic compounds such

as strong mineral acids and the heavy-metal chlorides. Most organic acids are classified as weak acids, and their corrosive attack, on most of the metallic materials used in chemical-processing equipment, might be expected to be mild. Although, in general, such assessment is correct, there are many exceptions, and the choice of materials for specific uses in the chemical industry must be carefully made, e.g., in food-processing equipment, where the introduction of even small amounts of metal salts into the products may seriously affect their quality. In view of the sparsity of data which can give practical guidance in selection of materials for such purposes, an investigation was made, at the U.S. Bureau of Mines, of the behaviour of titanium, zirconium, and 29–20 nickel-chromium steel containing molybdenum and copper (Carpenter No. 20). Specimens of these materials were exposed to the corrosive action of the following types of organic compound, both anhydrous and in aqueous solution, at several temperatures. The tests were made with apparatus described in the A.S.T.M. Tentative Method of Total Immersion Corrosion Tests of Non-Ferrous Metals.

Carboxylic Acids: formic, acetic, chloroacetic, lactic, and tannic acids.

Di- and Tri-carboxylic Acids: oxalic, tartaric, and citric acids.

Aniline Hydrochloride.

Chlorinated Hydrocarbons: carbon tetrachloride, chloroform, ethylene dichloride, trichloroethylene, tetrachloroethylene, tetrachloroethane.

Results of the individual series of tests are reported.

The general conclusions drawn are given below:—

'Titanium is resistant to attack by all concentrations of air-aerated formic acid, but is attacked severely by boiling 50 per cent. acid. It is only slightly resistant to this solution at 100°C. under oxygen-free conditions. This metal exhibits the phenomenon of 'borderline passivity' in certain concentrations of nitrogen-aerated 25 and 50 per cent. formic-acid solutions at 60° and 100°C. Corrosion rates for zirconium in formic acid are negligible. The 29–20 nickel-chromium steel, in contrast to titanium, is more resistant to oxygen-free formic-acid solutions than to those which are air-aerated.

'All three materials show excellent resistance to all concentrations of acetic acid. Stainless steel is appreciably attacked by boiling acetic anhydride and is severely attacked by boiling chloroacetic acid. Both titanium and zirconium are completely resistant to the latter corrodent. Titanium is much more resistant than zirconium to the action of boiling dichloroacetic acid. Neither metal is resistant to boiling trichloroacetic acid.

'Titanium, zirconium, and stainless steel of the type tested are fully resistant to all concentrations of air-aerated lactic, tannic, tartaric, and citric acids. Stainless steel shows appreciable corrosion in all concentrations of boiling lactic acid, whereas the other two materials are fully resistant. Corrosion rates for titanium and stainless steel in boiling 50 per cent. citric acid are appreciable, while those for zirconium are negligible. Titanium exhibits poor corrosion-resistance to even very dilute solutions of oxalic acid at elevated temperatures. In contrast, zirconium corrodes at very low rates. Stainless steel, while not comparable to zirconium, is far more corrosion-resistant than titanium in this solution.

'Titanium and zirconium give zero or negligible corrosion rates in air-aerated aniline hydrochloride solutions. Stainless steel is unsatisfactory because of a tendency to form deep pits. All three materials are resistant to boiling chlorinated hydrocarbon-water mixtures. With the exception of stainless steel in carbon tetrachloride, these materials also have little or no catalytic effect on the decomposition of the hydrocarbon under such conditions.'

Stainless Steels for Chemical Plant: Compositions and Properties

AMER. IRON AND STEEL INST., COMMITTEE OF STAINLESS STEEL PRODUCERS: 'Stainless Steels.' *Chemical Engineering*, 1953, vol. 60, Apr., pp. 290, 292, 294, 296–8, 300.

This article is introductory to a series of charts illustrating the resistance of stainless steels to attack by various corrosives. The present discussion covers the composition of stainless steels in general use (including U.S. specifications governing both wrought and cast grades), notes on physical condition of surfaces as affecting corrosion-resistance, the influence of variations in operating conditions and in fabricating practice, on corrosion-resisting characteristics, and the effect of design of stainless-steel parts on behaviour. The advisability of tests under actual or simulated service conditions is urged. Some typical uses of various grades of wrought stainless steel are listed.

'18–8 Stainless Steels.' *Chemical Engineering*, 1953, vol. 60, May, pp. 300–2, 304–6, 308, 310, 312.

This article is the first of three which will describe the properties of individual types of stainless steel. Some 130 charts indicate the degree of resistance which the 18–8 chromium-nickel steels offer to specific corrosives. Physical and mechanical properties of wrought 18–8 chromium-nickel steels are tabulated, and a list is given of the compositions of individual A.I.S.I. grades within this group.

'Carbidizing' Process for Case-Hardening of Stainless Steels

L. M. ALLEN and D. WOODARD: 'Case-Hardening of Austenitic Stainless Steels by the Carbidizing Process.' *Steel Processing*, 1952, vol. 38, Dec., pp. 615–20.

The authors describe investigations arising out of the requirement for a non-galling steel having high impact strength, which should remain relatively unaffected by long exposure in a mildly corrosive atmosphere. It was believed that such properties should be producible by case-hardening, but austenitic stainless steels treated by conventional carburizing processes have poor wear-resistance and are susceptible to intergranular corrosion, which has been attributed to combination of carbon with the chromium present in the steel.

The 'carbidizing process', which is described in this

paper, reduces chromium impoverishment of the matrix by introducing into the surface of the steel elements such as vanadium and titanium, which combine preferentially with the carbon. The mechanism of the 'carbidizing' process depends, firstly, on penetration of hydrogen into the steel, which results in expansion of the grain boundaries, and promotes formation of rifts along the crystallographic slip planes. It is assumed that formation of these voids and rifts sets up conditions of high-energy-level strain in localized regions of the lattice, and that these accelerate nucleation of complex chromium, vanadium, and titanium carbides, from the gas or metal which has diffused from the surface into the voids or rifts. The carbide, which has a hardness of 1500 D.P.N., develops as filaments along the grain boundaries, and as plates within the grains. The 'carbidized' surface is characterized by high resistance to wear, and possesses moderately good corrosion-resisting properties.

In the experiments described by the present authors, specimens of Type 303 stainless steel were packed in tightly sealed boxes in a proprietary compound ('Wilcarbo') containing carbon and salts of titanium and vanadium, and the boxes were heated for various times and at various temperatures. The results are presented in curves showing case depth and surface hardness as functions of temperature for a given time, and the effect of time at constant temperature on the depth of the 'carbidized' layer. Surface hardness (but *not* the hardness of the carbide) increased with rise of 'carbidizing' temperature, but temperatures above 1950°F. (1063°C.) caused pitting of the surface of the steel, and fusion of the case-hardening compound occurred. A two-hour treatment at the optimum 'carbidizing' temperature, 1900°F. (1037°C.) produced a case depth of approximately 0·035 inch.

The surface of the steel remained non-magnetic after the 'carbidizing' treatment, and although the standard copper sulphate/sulphuric acid (Strauss) test produced definite attack of the matrix, resistance to boiling salt solution and to dilute acetic acid was good.

The results lead the authors to the conclusion that 'carbidizing' could usefully be applied by manufacturers called upon to produce machined stainless-steel parts in which a wear-resistant surface is essential.

Clad Steel Plate: Manufacture and Properties

See abstract on p. 109.

Filters made by Powder Metallurgy

See abstract on p. 108.

PATENTS

Nickel Electrodes for Alkaline Accumulators

A porous plate, e.g., of sintered carbonyl-nickel powder, is impregnated with an aqueous solution of a base, dried, and subsequently immersed in a solution of a salt of a metal the hydrate of which is precipitated by the base used, e.g., $NiSO_4$ precipitated by soda or potash.

P. A. C. JACQUIER. *French Pat.* 1,017,110.

Iron-containing Copper-Nickel Alloys for Condenser Tubes

The patent covers iron-containing alloys developed by the British Non-Ferrous Metals Research Association. The limits given are: nickel 12·5–25, iron 0·5–4·0, per cent., optionally up to 1·0 per cent. manganese, balance copper.

E. A. G. LIDDIARD and R. MAY, assignors to BRITISH NON-FERROUS METALS RESEARCH ASSCN.
Canad. Pat. 491,837.

Nickel Additions to Zinc-base Alloys

The wear-resistance of zinc-base alloys is increased by addition of nickel 0·16–3·0 per cent. (preferably 1–2·5 per cent.) and titanium 0·04–0·8 per cent. (preferably 0·2–0·6 per cent.). The alloys may also contain magnesium 0·03–0·4, aluminium 3–5, copper 2–3·5, per cent. The nickel and titanium are preferably added to the zinc-base alloys as a ternary alloy containing copper 45–90, nickel 8–40, titanium 2–15, per cent.

GENERAL MOTORS CORPN., assignee of J. C. HOLZWARTH.
Brit. Pat. 691,238.

Coated Nickel-Alloy-Cored Welding Electrodes

British Patent 611,802 described welding electrodes comprising a core wire of an alloy containing nickel 75 min., chromium 10 min., iron 10 max. per cent., having a flux-forming covering, preferably of the following composition: calcium carbonate 37–47, calcium fluoride 20–30, ferro-titanium 5–20, ferro-niobium 0–30, bentonite 2–5, dextrine 1–5, per cent. These electrodes could be used with both alternating and direct current.

When used with direct current, however, they were found, unless baked immediately before use, to have a tendency to produce porous welds. This tendency was reduced or eliminated (according to *British Patent* 668,054) by lowering the calcium carbonate content of the flux and including cryolite as all or part of the fluoride content of the coating. The revised specification for the coating thus stood at: calcium carbonate 15–35, calcium fluoride 0–30, cryolite 20–45, niobium (as ferro-niobium) 2·5–15, titanium (as ferro-titanium) 4, bentonite 2–5, per cent. The improved form of electrode failed to give consistently sound welds when used with alternating current, and a later specification, *British Patent* 689,823, covers a still further modification of composition of the coating. The limits now specified are calcium carbonate 10–30, barium fluoride 9–25, cryolite 10–50, niobium (as ferro-niobium) 1·5–16, titanium (as ferro-titanium) 0·2–4·8, bentonite 2–5, per cent., and up to 25 per cent. of iron, added as the ferro-alloys.

MOND NICKEL CO., LTD.
Brit. Pats. 611,802, 668,054; 689,823.

Cobalt-Nickel-Iron Magnetic Alloy

A magnetic alloy, which is capable of being cold worked and is especially useful for rotors for hysteresis motors, contains nickel 5–7, vanadium 4–6, cobalt 43–47, per cent., balance iron. It has a coercive force

of 50 to 100 oersted and a B_r at least 12,000 gauss. The preferred composition is nickel 6·1, vanadium 4·4, cobalt 45·6, per cent., balance iron.

BRITISH THOMSON–HOUSTON CO., LTD.
Brit. Pat. 688,889.

Weldable High-Tensile Nickel-Alloy Steel

A composition claimed to give weldable steel of high tensile strength is cited as carbon 0·14–0·19, silicon 0·60–0·80, manganese 0·80–1·50, nickel 0·80–1·80, chromium 0·50–0·90, per cent., and optionally one or more of the following elements:— molybdenum up to 0·30, vanadium up to 0·25, copper up to 0·80, per cent., balance iron.

'TERNI' SOCIETA PER L'INDUSTRIA E L'ELETTRICITA.
Brit. Pat. 688,617 (Corresponding to *U.S. Pat.* 2,565,953).

Heat-Resistant Copper-Nickel Steels

A steel showing a high elastic limit at 350°C. and a favourable tensile strength: elastic limit ratio at room temperature is of the following composition: carbon 0·1–0·3, manganese 0·6–1·0, copper 0·6–1·2, nickel 0·5–1·2, silicon 0·3–0·5, molybdenum 0–0·3, chromium 0–0·4, per cent., with one or more of the elements tantalum, niobium, boron, zirconium, in trace amounts up to 0·06 per cent., balance iron. A heat-treatment suitable for the steel is specified.

RHEINISCHE RÖHRENWERKE, A.G. *Brit. Pat.* 689,503.

Complex Heat-Resisting Steels

Steels claimed to show good mechanical strength at temperatures up to 800°C., and to be characterized by satisfactory working properties, are of the following composition:—carbon up to 0·20, silicon up to 1, manganese up to 2, chromium 12–20, nickel 12–20, molybdenum 0·5–3, per cent., together with small amounts of tungsten and niobium, and, optionally, tantalum, vanadium, cobalt; balance iron.

GEBR. BOEHLER AND CO., A.G. *Belgian Pat.* 513,919.

Austenitic Steels for High-Temperature Plant

Steels suitable for service at 800–1300°F. (425°–705°C.), in chemical plant, turbines, internal-combustion engines, etc., contain chromium 15–19, nickel 7–12, carbon 0·03–0·10, boron 0·01–0·10, per cent., with a carbide-former (titanium, niobium, tantalum, zirconium), present in amounts 4–12·7 times the carbon content, balance iron. The steels are preferably heat-treated by quenching from above 1900°F. (1035°C.) and tempering at 900°–1500°F. (480°–815°C.).

NATIONAL LEAD CO., assignee of S. F. URBAN and G. F. COMSTOCK.
Brit. Pat. 689,832. (Corresponding to *U.S. Pat.* 2,602,028).

Heat-Treatment of Creep-Resisting Ferritic Nickel-Alloy Steel

The heat-treatment specified below is claimed to improve the creep-resistance of hypoeutectoid ferritic nickel steel of the following composition:— nickel 0·25–3·0, chromium 0–1·5, molybdenum 0–0·3, manganese 0·25–1·0, vanadium 0–0·3, carbon 0·1–0·75, per cent., balance iron.

The steel is heated at a temperature between the Ac_3 point and 2300°F. (1260°C.) for 1 to 5 hours per linear inch of cross-section, cooled at a rate faster than the critical cooling rate to a temperature 50°–150°F. (28°–83°C.) below the Ae_1 point, and held at that temperature for 2 to 10 hours. Such treatment transforms the structure of the steel to a coarse-grained austenite.

MOND NICKEL CO., LTD. *Brit. Pat.* 688,858.

Nickel-Alloy Armouring of Valve Heads

Service behaviour of valves is improved by welding a pre-formed ring of a heat-resisting, wear-resisting and/or non-corroding material on to the valve head. A composition suitable for the pre-formed ring is given as nickel 50–80, chromium 10–20, carbon 0·10–1·0, silicon 2·0–6·0, manganese 0·10–2·0, per cent., balance iron.

DEUTSCHE EDELSTAHLWERKE, A.G.
Brit. Pat. 689,817.

Complex Nickel-Chromium-Iron Alloys for Electrical-Resistance Elements

Alloys for electrical-resistance elements contain nickel 30–70, chromium 10–25, calcium 0·01–0·20, aluminium 0·07–0·4, per cent., rare-earth metals in traces up to 0·50 per cent., balance iron. The following may also be present: manganese 0·02–4·0, silicon 0·20–3·0, carbon up to 0·25, per cent. A.S.T.M. test lives are quoted for typical alloys.

BRITISH DRIVER–HARRIS CO., LTD., communication from DRIVER–HARRIS CO.
Brit. Pat. 690,241. (Corresponding to *U.S. Pat.* 2,581,420).

Magnesium Treatment of Stainless Steel

The ductility of austenitic steels is enhanced by treatment, when molten, with 0·1–0·4 per cent. of magnesium. The range of steels specified is as follows: chromium 25–30, nickel trace to 4·0, molybdenum trace to 2·0, carbon up to 0·2, per cent., with the usual amounts of silicon, manganese, sulphur, and phosphorus; balance iron. Magnesium-treated steels of this type are claimed to give at least 10 per cent. elongation, and 10 per cent. reduction of area.

N. A. ZIEGLER, J. R. GOLDSMITH, A. F. LAHR, assignors to CRANE CO.
U.S. Pat. 2,616,798.

Attention is drawn to the fact that many of the names of materials mentioned in The Nickel Bulletin are *Registered Trade Marks.*

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